

Equilibrium (Zipf) and Dynamic (Grasseberg-Procaccia) method based analyses of human texts. A comparison of natural (english) and artificial (esperanto) languages.

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Abstract

A comparison of two english texts from Lewis Carroll, one (Alice in wonderland), also translated into esperanto, the other (Through a looking glass) are discussed in order to observe whether natural and artificial languages significantly differ from each other. One dimensional time series like signals are constructed using only word frequencies (FTS) or word lengths (LTS). The data is studied through (i) a Zipf method for sorting out correlations in the FTS and (ii) a Grassberger-Procaccia (GP) technique based method for finding correlations in LTS. Features are compared : different power laws are observed with characteristic exponents for the ranking properties, and the *phase space attractor dimensionality*. The Zipf exponent can take values much less than unity (*ca.* 0.50 or 0.30) depending on how a sentence is defined. This non-universality is conjectured to be a measure of the author *style*. Moreover the attractor dimension r is a simple function of the so called phase space dimension n , i.e., $r = n^\lambda$, with $\lambda = 0.79$. Such an exponent should also conjecture to be a measure of the author *creativity*. However, even though there are quantitative differences between the original english text and its esperanto translation, the qualitative differences are very minutes, indicating in this case a translation relatively well respecting, along our analysis lines, the content of the author writing.

Key words: Econophysics, recession, prosperity, Latin America

1 Introduction

Human languages are systems usually composed of a large number of internal components (the words, punctuation signs, and blanks in printed texts) and

rules (grammar). Relevant questions pertain to the life time, concentration, distribution, .. complexity of these and their relations between each others. Thus human language is a new emerging field for the application of methods from the physical sciences in order to achieve a deeper understanding of linguistic complexity [1,2,3,4,5]. Language distributions, competitions, life durations, ... have become an active field of research in statistical physics indeed since [4,5,6,7], where usual techniques based on non-equilibrium considerations [8], and agent based models are already much applied

One should distinguish two main frameworks. On one hand, language developments seem to be understandable through competitions, like in Ising models, and in self-organized systems. Their diffusion seems similar to percolation and nucleation-growth problems taking into account the existence of different time scales, for inter- and intra- effects. The other frame is somewhat older and originates from more classical linguistics studies; it pertains to the content and meanings [9,10]. This latter case is of interest here and the main subject of the report, within a statistical physics framework.

Concerning the internal structure of a text, supposedly characterized by the language in which it is written, it is well known that a text can be mapped into a signal, of course first through the alphabet characters. However it can be also reduced to less abundant symbols through some threshold, like a time series, which can be a list of +1 and -1, or sometimes 0. Thereafter one could apply at this stage many techniques of signal analysis.

In fact, laws of text content and structures have been searched for a long time by e.g. Zipf and others [11,12,13,14,15] through the least effort (so called ranking) method. The technique is now currently applied in statistical physics as a first step to obtain, when they exist, the primary scaling law. It has been somewhat a surprise that the number of words $w(h)$ which occurs h times in a text is such that $w(h) \sim 1/h^\gamma$, where $\gamma \sim 2$, while the rank R of the words according to their frequency f behaves like another power law $f \sim R^{-\zeta}$ where the exponent ζ is quasi always close to 1.0 [16]. Some thought has been presented to explain so, based on constrained correlations [17,18]. Another distribution has been studied, i.e. the distribution of word lengths in a text. Whence two features can be looked for (i) word frequencies (FTS) or (ii) word lengths (LTS). We hereby consider that in physics terms they represent different measures of the system : the first one leads to characterizing the spanned phase space through a measure, - it is a static-like, equilibrium approach, obtained *after* the text is finalized, while the second rather contains a time *evolution* aspect : it takes more time to pronounce (or read) a long word than a small one. Whence another technique of analysis than the Zipf one should be put forward. We implement the Grassberger-Procaccia (GP) technique for finding "time correlations" in the text through the analysis of LTS, as a signal spanning some attractor in a space on an *a priori* unknown

dimension.

Obviously there are many ways to map a text onto a time series, but in the present study the above two series are only considered, due to their physical meaning which can be thought to be implied in the mapping.

No need to recall the many communications in which a comparison of the properties of such "time signals" has been presented, - sometimes even (very) artificial so called languages [14] have been discussed, like those used for simulation codes on computers [19]. Comparison of different truly human languages arising from apparently different origins or containing different signs has also been made, e.g. beside english, one can find references about greek [20,21,22], turkish [23], chinese [24], ... "Linguistic time series" have often studied at a letter or word level [25,26,27,28] or as in Montemurro and Pury [27,28] at a frequency mapping, similar though not identical to the one described below. Others have considered Zipf law(s) at the sentence level [29,30], - a few sometimes strangely neglecting the punctuation [31,32].

Esperanto is an artificially and somewhat recently constructed language [33], which was intended to be an easy-to-learn lingua franca. Previous statistical analyses seem to indicate that esperanto's statistical proportions are similar to those of other languages [34]. It was found that esperanto's statistical proportions resemble mostly those of German and Spanish, and somewhat surprisingly least those of French and Italian. By the way, english seems to be an intermediary case [15]. Yet there are quantitative differences : English contains ca. 1 M words [35], esperanto 150 k words [36]. Other artificial languages exist, like that of the Magma [37] and Urban Trad [38] music groups, the latter specifically designed for song competition, i.e. the eurovision contest [39]. Like in e.g. rap music lyrics or french *verlan*, the thesaurus is rather of limited size in all these cases.

To my knowledge few comparisons exist on texts translated from one to another language [40,41,42,43], in particular into artificial languages. We present below an original consideration in this respect, the analysis and results about a translation between one of the most commonly used language, i.e. english, and a relatively recent language, i.e. esperanto.

The text to be used was chosen for its wide diffusion, freely available from the web [44] and as a representative one of a famous scientist, Lewis Carroll, i.e. *Alice in wonderland* (AWL) [45]. Moreover knowing the special (mathematical) quality of this author's mind, and some, as I thought *a priori*, possibly special way of writing, a bench mark has been chosen for comparison, i.e. *Through a looking glass* (TLG) [46]; - alas to my knowledge only available in english on the web [47]. Yet this will allow us to discuss whether the difference, if any, between esperanto and english, are apparently due to the translation or on the

contrary to the specificity of this author's work. It might be also expected that one could observe whether some style or vocabulary change has been made between two texts having appeared at different times : 1865 and 1871, or not. Previous work on the english AWL version should be mentioned [15], where the discussion mainly pertains on corpus size effect on the validity of Zipf law, but where is emphasized a relevant ingredient to be taken into account in discussing most written texts, i.e. a mixing of oral and descriptive accounts.

In Sect. 2, a few elementary facts and basic statistics on these texts are presented; the methodology is briefly exposed, i.e. as one recalls (i) two simple ways to map texts into *signals*, i.e., the frequency time series (FTS) and the (word) length time series (LTS) , (ii) the Zipf ranking technique, (iii) the Grassberger-Procaccia (GP) method [48,49] used for finding correlations. Similar techniques for comparing english and greek texts, but not from a translation point of view can be found in [20]; however the published work contains a few annoying (misprints or) defects which induces us to reformulate the techniques when applied to the present problem. In Sect. 3, the results are presented : (i) a Zipf analysis on the frequency time series (FTS), (ii) a GP analysis for the (word) length time series (LTS). The results are discussed in Sect. 4.

2 Data and Methodology

For these considerations two texts here above mentioned and one translation have been selected and downloaded from a freely available site [44], resulting obviously into three files. The chapter heads have been removed. All analyses are carried out over this reduced file for each text. Basic statistics, like the number of words, the longest sentence, ... are given in Table 2 for each text, and chapters. A few facts attract some attention

- (1) the number of dots is *much smaller* in AWL_{eng} than in AWL_{esp} and also in TLG_{eng}
- (2) automatically the longest sentence occurs in AWL_{eng} with many more characters
- (3) the longest sentence in AWL_{esp} occurs between commas
- (4) the number of semi columns is very small in TLG_{eng}
- (5) the longest sentence ever occurs in TLG_{eng} between semi-columns
- (6) there are *very few* exclamation marks in AWL_{esp}
- (7) but a long sentence is then found between these in such a work
- (8) more importantly the number of sentences is much smaller in AWL_{eng} than in AWL_{esp}.

	AWLeng	AWLesp	TLGeng
Number of words	27342	25592	30601
Number of different words	2958	5368	3205
Number of characters	144927	154445	164147
Number of punctuation marks	4481	4752	4828
Number of "sentences"	1633	2016	2059
Words in chap. 1	2194	1858	
Different words in chap. 1	652	853	
Words in chap. 2	2188	1915	
Different words in chap. 2	665	829	
Number of dots	979	1545	1315
Longest "sentence"	1669	825	864
Number of commas	2419	2324	2441
Longest "sentence"	373	1170	368
Number of semi columns	195	207	72
Longest sentence	6624	6043	12501
Number of columns	234	205	256
Longest sentence	4586	5576	3145
Number of question marks	203	205	254
Longest sentence	6323	5581	5212
Number of exclamation marks	451	266	490
Longest sentence	4388	6249	4016

Table 1

Basic statistical data for the three texts of interest; in each case the longest sentence is measured in terms of the number of characters (not in terms of words)

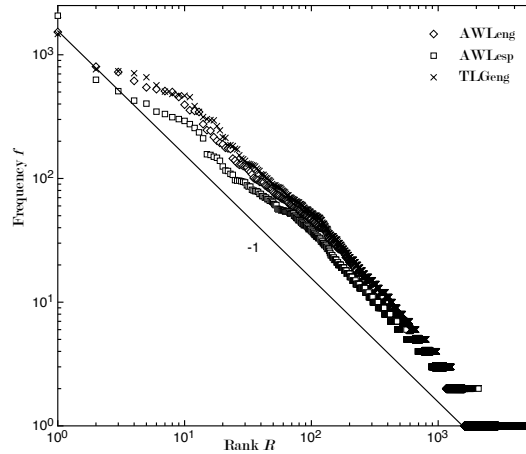


Fig. 1. Zipf (log-log) plot of the frequency of words in the three texts of interest AWLeng, AWLesp and TLGeng. The usual ($\zeta = 1$) exponent is indicated. A Zipf-Mandelbrot law fit for $2 \leq R \leq 1000$ is not shown but is discussed in the main text; see also table III

Let us now search for correlations in the texts through both ways of constructing a time series from such documents of e.g. M words:

- (1) Count the frequency f of appearance of each word in the document. Rewrite the text such that at each "appearance" of a word, the word is replaced by its frequency such that one obtains a time series $f(t)$. Such a time series is called a "frequency time series" (FTS).

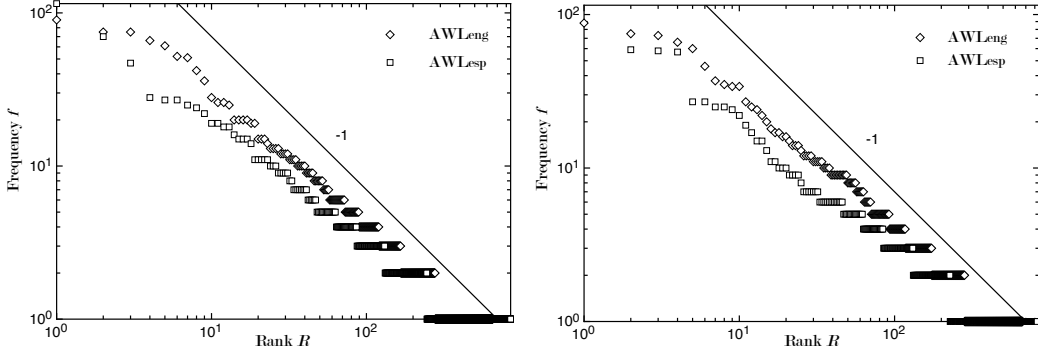


Fig. 2. Zipf (log-log) plot of the frequency of words in (a) chapter 1, (b) chapter 2, for the texts of interest, i.e. AWLeng and AWLesp. The "usual" 1 exponent is indicated. A Zipf-Mandelbrot law fit for $R \leq 200$ is not shown but is discussed in the main text; see also table III

- (2) Count the number l of letters of each word located in the text successively at the $time t = 1$, for the first word, at time $t = 2$, for the second, etc. Construct a time series $l(t)$. Henceforth, such a time series is called a length time series (LTS).

When applied e.g., to economic (financial) signals [50,51,52,53], each frequency f and word length l are analogous to the price of a share or the volume of a transaction. A (scaling or) power law is then often observed, i.e. when correlated sequences exist, leading to $\zeta_{m,k}$ values quite different from 1.

These two sorts of time series are thereby analyzed along one of the two mentioned techniques, one being more pertinent than the other as outlined here above. Let us discuss them briefly.

2.1 Zipf method

A large set of references on Zipf's law(s) in natural languages can be found in [54]. The idea has been applied to many various complex signals or "texts", - signals, translated through a number k of characters characterizing an alphabet, like, among many others, for time intervals between earthquakes [55], DNA sequences [56] or for financial data [50,51,52] along the lines of econophysics.

The (FTS) Zipf original method (though see [13]) [11,57,58] examines the probability distribution of words in spoken (more exactly written) languages. Zipf calculated the number N of occurrences of each word in a given text. By sorting out the words according to their frequency f , i.e. N measured with respect to the total number M of words in the text, a rank R can be assigned to each word, with $R = 1$ for the most frequent one. For any natural languages,

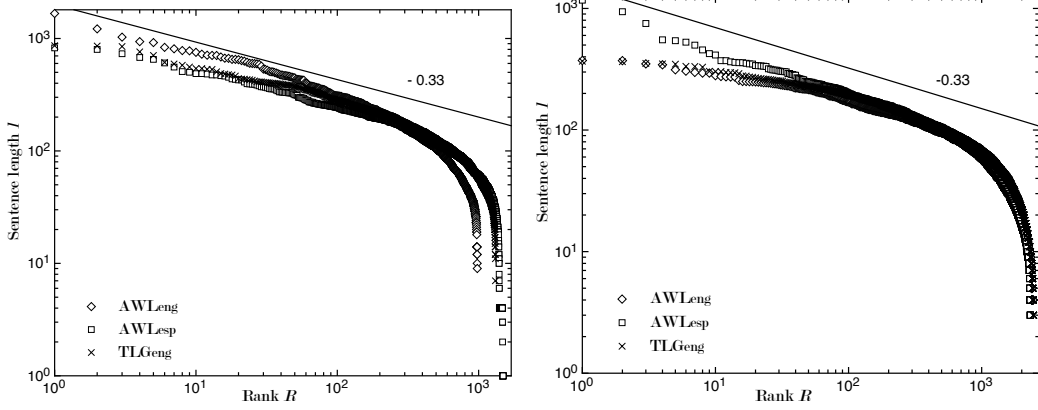


Fig. 3. Zipf (log-log) plot of the FTS of sentence lengths, as separated by (a) dots, (b) commas, in the three texts of interest AWLeng, AWLesp and TLGeng. The 0.33 exponent of the corresponding Zipf law is indicated as a guide to the eye. A Zipf-Mandelbrot law fit for $R \leq 200$ is not shown but is discussed in the main text; see also Table III

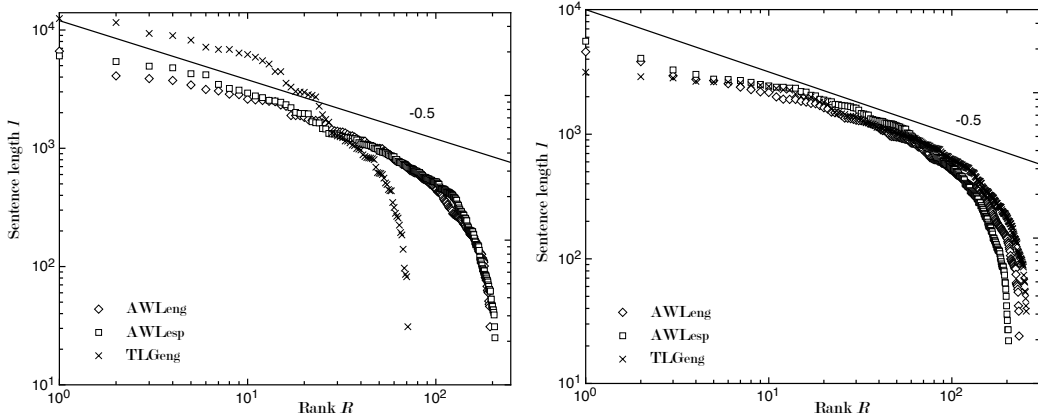


Fig. 4. Zipf (log-log) plot of the FTS of sentence lengths, as separated by (a) semi-columns, (b) columns, in the three texts of interest AWLeng, AWLesp and TLGeng. The 0.50 exponent of the corresponding Zipf law is indicated as a guide to the eye. A Zipf-Mandelbrot law fit for various R ranges is not shown but is discussed in the main text; see also Table III

one observes a power law for the rank distribution

$$f \sim R^{-\zeta} \quad (1)$$

with an exponent ζ close to unity. The occurrence of this power law has already been suggested [60] to be due to the "hierarchical structure" of the text as well as the presence of long range correlations (sentences, and logical structures therein). This strong quantitative statement with ubiquitous applicability is attested over a vast repertoire of human languages [16]. Yet it is of empirical evidence that Zipf's law in this (FTS) form can at most account for the statistical behaviour of words frequencies in a zone spanning the middle-low to low range of the rank variable. Even in the case of long single texts

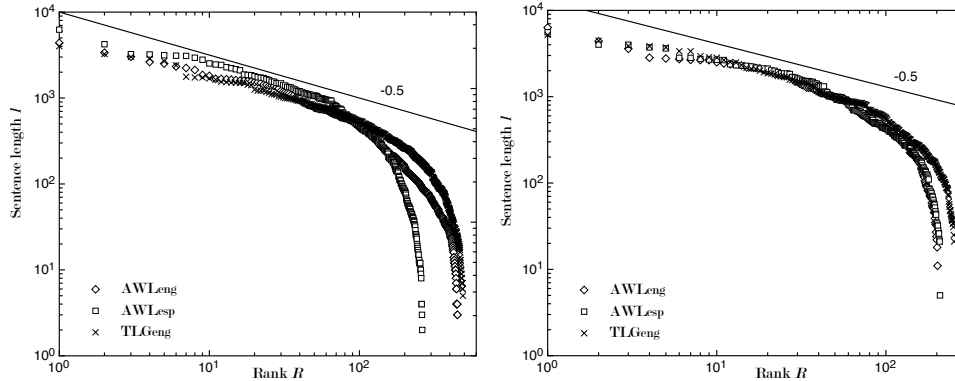


Fig. 5. Zipf (log-log) plot of the FTS of sentence lengths, as separated by (a) exclamation points, (b) question marks, in the three texts of interest AWLeng, AWLesp and TLGeng. The 0.50 exponent of the corresponding Zipf law is indicated as a guide to the eye. A Zipf-Mandelbrot law fit for various R ranges is not shown but is discussed in the main text; see also Table III

Zipf's law renders an acceptable ζ in the small window between $s \simeq 10$ and 1000, which does not represent a significant fraction of any literary vocabulary. However power laws lead to valuable insights into statistical processes, since they imply no scaling, whence some hierarchical structure. The ζ exponent, or more generally the exponent of such a power law, can be turned into a *fractal dimension* (or Hurst exponent) interpretation as in [61].

One difficulty stems in the lower and upper ranks of such plots because of the abundance and rarity of words [62]. Mandelbrot [63,64,65] using arguments based on *fractal* ideas, applied to the structure of lexical trees, improved the original form of the law, writing, in terms of two parameters A and C that need to be adjusted to the data,

$$f(R) = \frac{A}{(1 + CR)^{\zeta^*}}. \quad (2)$$

The latter form is thought to be more adequately valid for many sorts of data in the region corresponding to the *lowest* ranks, that is $R < 100$, dominated by mostly (small) function words. In the same spirit one can show that $w(h) \sim 1/h^{1+\nu}$ [66]; whence $\gamma = 1 + \nu$, with $\nu = 1/\zeta$ or ζ^* [67,68]. We do not discuss further the validity of Zipf law(s) for which there is an abundant literature [54].

It has been shown that this Zipf-Mandelbrot law is also obeyed by so many random processes [69,70] that one has been sometimes ruling out any interestingly special character for *linguistic* studies. Nevertheless, it has been argued that it is possible to discriminate between human writings [71] and stochastic versions of texts precisely by looking at statistical properties of words that fall where Eq.(1) does not hold [20]. Whence still some question cannot be avoided on artificial languages, translations, and on effects resulting from automatic

AWLeng	f	AWLesp	f
the	1527	la (=the)	2070
and	802	kaj (=and)	628
to	725	š i (=she)	508
a	615	ne (=no/not)	426
I	545	mi (=I)	403
it	527	Alicio (=Alice)	347
she	509	diris (=said)	332
of	500	al (=to)	313
said	456	vi (=you)	302
Alice	395	ke (=that)	292

Table 2

Top ten most frequent words in AWLeng and AWLesp with their frequency

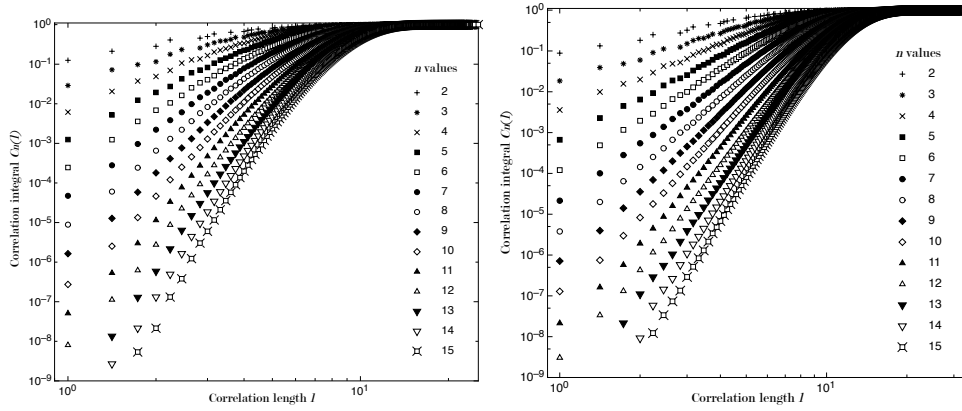


Fig. 6. Grassberger-Procaccia (log-log) plot of the correlation integral $C_n(l)$ as a function of the correlation length l in different phase space dimension n , see text, in the two texts of interest (a) AWLeng and (b) AWLesp

or machine translations [43].

Flipping the horizontal and vertical axes of the log-log plot suggested by Eq. (1) the cumulative probability distribution function (cPDF) $P(f)$ of the quantities of interest obeys

$$P(\geq f) \sim f^{1-\eta} \quad (3)$$

where $1-\eta$ is a characteristic power law exponent for the cPDF. Whenceforth, $\eta - 1 = 1/\zeta$; i.e. $p(f) \simeq f^{-\eta}$.

Note that in the following the length of sentences is also examined from the point of view of the numbers of characters between (six sorts of) punctuation marks, see Table 1. One also distinguishes between the first and second chapter, thereby allowing for some consistency test.

2.2 Grassberger-Proccacia method

In order to get an insight into the dynamics of a system solely from the knowledge of the time series, a method derived by Grassberger and Proccacia [48,49] has been proven to be particularly useful. This method has been applied to analyze the dynamics of neural network activity [72], electric activity of semi-conducting circuits [73,74], climate [75], etc.

We aim to finding some answer to questions like

- (1) Can the salient features of the system be viewed as the manifestation of a deterministic dynamics, or do they contain an irreducible stochastic element?
- (2) Is it possible to identify an attractor in the system phase space from a given time series [76]?
- (3) If the attractor exists, what is its dimensionality r [77]?
- (4) What is the (minimal) dimensionality n of the phase space within which the above attractor is embedded [78]?

This defines the minimum number of variables that must be considered in the description (through some model) of the system.

This is done as follows: Let the LTS time series having M data points, i.e. y_i ($i = 1, \dots, M$). Consider the data as illustrating some dynamical process in a (phase) space with dimension n . Construct a set of V vectors v_k ($k = 1, \dots, V$) containing $n - 1$ points as follows:

$$v_k = (y_k, y_{k+\tau}, y_{k+2\tau}, \dots, y_{k+(n-1)\tau}) \quad (4)$$

where τ is an integer, called the *delay time*. Notice : $V + (n - 1) = M$. In other words, one considers $k + n\tau$ as a sum modulo M . Next one estimates the correlation integral from the *distance* $|v_i - v_j|$ between all the vectors such that $1 \leq i, j \leq V$. The correlation integral $C_n(l)$ is obtained from

$$C_n(l) = \frac{\# \text{ of pairs } (i, j) \text{ such that } |v_i - v_j| < l}{N^2}. \quad (5)$$

In other words,

$$C_n(l) = \frac{\# \text{ of pairs } (i, j > i) \text{ such that } |v_i - v_j| < l}{N(N - 1)/2}. \quad (6)$$

GP have shown that for small l , one has

$$C_n(l) \simeq Bl^r. \quad (7)$$

where B is some constant and r is the so called *attractor (correlation) dimension*, measuring the number of dynamic variables or number of degrees of freedom. In order to obtain r for the different n values, a log-log plot is in order. The choice of τ is debatable[79]. In the following we have chosen $\tau = 500$ like in other related studies [20], for $n = 1$ to 15.

Practically, it was noticed that the correlation integral calculated for $|v_i < v_j|$ distances takes a finite number of values; therefore each distance l was "measured" up to three decimal digits. Therefore two distances differing by less than 0.001 are not differentiated. Even though we have not tested the robustness of this "numerical approximation", we have not the impression that it is a drastic one.

A fit of the beginning of the $C_n(l)$ evolution through the best mean square technique on a log-log plot leads to a value of the relevant slopes, thus r defined by Eq. (7).

3 Results

3.1 Zipf plots

The result of the FTS analysis for the three main texts is shown in Fig. 1. Figs. 2(a-b) show the (frequency, rank) relation for the esperanto and english chapter 1 and 2 respectively of both AWL texts. Each log-log plot roughly indicates a linear relationship, for $R \geq 10$, thus a ζ exponent close to unity, as often found, in usual literature. Some curvature is found for all texts below $R \sim 15$ where a so called discontinuity exists, explained by [15] as due to a transition between colloquial ("common") small and "distinctive" words. Some break, or change in slope, is also found ca. 100, - see discussion in [15]. More interestingly let it be observed that the Rank =1 for the esperanto text is much higher than for the english texts. Moreover the variety of distinct words is larger in esperanto as well. In between the number of words is less frequent in general, indicating a greater simplicity in vocabulary. The same is true whatever the chapter considered.

The top ten most frequent words in AWL_{eng} and AWL_{esp} are given with their frequency in Table 2.1. It seems of interest to point out differences in style appearing from such a table. Notice that a translation does not conserve

Fig.	Text	A	C	ζ^*	Range
					$\dots \leq R \leq \dots$
1	AWL _{eng}	1177	0.17	1.15	2 1000
	AWL _{esp}	962	0.28	1.01	2 1000
	TLG _{eng}	1098	0.13	1.21	2 1000
2a	AWL _{eng}	116	0.19	1.16	1 200
	AWL _{esp}	48	0.15	0.01	4 200
2b	AWL _{eng}	118	0.24	1.07	1 200
	AWL _{esp}	168	0.90	0.92	2 200
3a	AWL _{eng}	1062	0.08	0.55	4 200
	AWL _{esp}	984	0.5	0.36	1 200
	TLG _{eng}	1029	0.46	0.34	1 200
3b	AWL _{eng}	366	0.09	0.33	1 200
	AWL _{esp}	1019	1.2	0.34	4 200
	TLG _{eng}	382	0.11	0.27	1 200
4a	AWL _{eng}	4650	0.06	1.15	2 100
	AWL _{esp}	6978	0.14	0.97	1 100
	TLG _{eng}	13128	0.02	4.73	1 60
4b	AWL _{eng}	5068	0.34	0.59	1 100
	AWL _{esp}	5645	0.3	0.6	1 100
	TLG _{eng}	3296	0.05	0.94	1 100
5a	AWL _{eng}	2756	0.03	1.48	4 200
	AWL _{esp}	3630	0.02	1.91	3 200
	TLG _{eng}	4777	0.39	0.61	1 200
5b	AWL _{eng}	3283	0.01	3.61	4 100
	AWL _{esp}	4099	0.02	1.89	2 100
	TLG _{eng}	5504	0.13	0.84	1 100

Table 3

Values of parameters for the Z-M fit, Eq. (2); the corresponding figure and texts are indicated together with the fit range

the number of words in a text, nor their importance in frequency. Of course the ranking might be intrinsically different, but also the translator can modify some sentences according to the language and grammar. An interesting illustration is noticed in Table 2.1 : the same words '*the*'=*'la'* and '*and*'=*'kaj'* are both times the most frequent, but for example '*Alice*' occurs more frequently in the english text than in the esperanto text, same for '*I*'=*'mi'*, even though '*she*'=*'ŝi'* occurs an equal number of times.

As indicated in the main text, one can look at the length of sentences, in the case of the three main texts, Figs. 3-5. The relevant separators are mentioned in the figure captions. A marked difference occurs between the cases “.” (dot) and “,” (comma) on one hand and the others, column, semi-column, exclamation point, question mark, i.e., “:”, “;”, “!”, “?”. In the first group, the slope is rather close to 1/3, but is closer to 1/2 for the latest four cases. The number of punctuation marks is relatively equivalent (see Table 2) in all texts, but the number of dots and commas are much larger than the other punctuation marks. Therefore one might expect some finite size effect. Whence it is of interest to test Eq.(2), and compare the parameter values, given in Table 3.1.

From the figures one can notice that three exponents seem to characterize the rank law 1.0, 1/3, 1/2. The unity is *usual*. To find low values like 0.5 and 0.33

is more rare. Let us refer to a case in which it was striking to find a value ca. 0.55 and 0.72, i.e. the case of city size, in 1600 and 1990 respectively, and 0.74 for firm sizes with more than 10 employees in 1997, in Denmark [80], in contrast to the usual 1.0 value [81]. A value smaller than unity indicates a more homogeneous repartition of the variables (words, here). One can see some analogy between city and firm sizes from the point of view of flow in (and out) of citizens or assets. Whence a Gabaix [81] or Simon [82] model can be thought of to understand the values found here. E.g. Gabaix claims that two causes can lead to a value less than 1.0, i.e. either :

- (1) the mean or variance of the growth process deviates from Gibrat's law [83], i.e. the growth rate is independent of the size, or
- (2) the variance of the growth process depends is size-dependent.

Recalling that one does not examine the "growth" of the text at this stage yet, nor have any model for doing so presently, - except that of Simon [82] (words not yet used are added at a constant rate, while words already used are inserted at a frequency depending of the previous number of occurrences; this leads to Zipf law; thus the rate of appearance of new words in fact decreases as the text length increases), one can nevertheless agree that the sample size is relevant for finding a small ζ value. Indeed it is clear that the found values correspond to the length of sentences which are defined through various punctuation marks, counting characters rather than words. Several orders of magnitude in the maximum rank distinguish the cases. What is still surprising is why the longest sentences, thus defined through dots and commas lead to a smaller values than for other punctuation marks which lead to less frequent sentences.

An alternate view can be taken through the Z-M analytical form, Eq.(2). Values of the parameters are given in Table 3 for various ranges R . it is fair to state that the parameters are NOT very robust with respect to the range. Values of ζ^* can be found close to the apparently best looking slope, ζ , but other values can be found as well. This is due to the strong influence of the low rank points. The paradoxical situation occurs when one remembers that the analytical form is supposed to be used in order to take into account the finite value at $R = 1$. However the curvature for the (small) function words markedly influences the outcome. In order to illustrate the point, a brief example is given in an Appendix.

3.2 *Grasseberger-Procaccia plots*

The analysis of correlation integrals allow to estimate whether the number of degrees of freedom (of a process) is large or reasonably small. It seems that the usual goal is rather qualitative. However it pertains to the fundamental

Text	Slope $r(n)$	Standard deviation
AWLeng	0.84	0.01
AWLesp	0.747	0.004
TLGeng	0.77	0.01
Global	0.79	0.01

Table 4
Measured slopes of the linear function $r(n)$

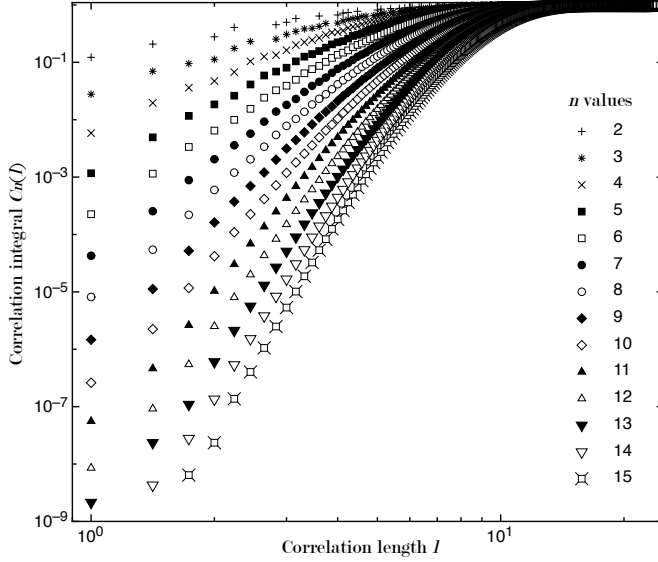


Fig. 7. Grassberger-Procaccia (log-log) plot of the correlation integral $C_n(l)$ as a function of the correlation length l in phase spaces with different dimensions (n) for TLGeng

question on noisy signals, - is it noise or chaos? As explained here above the algorithm is based on the statistics of pairwise distances for an arbitrary choice of the delay time. Therefore the output of the method results in observing an evolution of correlations, i.e. in the knowledge on how often a point in some ((= "the") phase space is found near another, whence illustrating some dynamical features connecting local and global features.

The three sets of correlation integrals, calculated following the method here above described, are shown in Figs. 7-8. The slopes can be summarized through a graph relating r and n (Fig.9). It is found that the attractor dimension n is not only smaller than the space dimension, as it should be [78], but also is a linear function on a log-log plot of the so called phase space dimension r , *for the three texts of interest*. A remarkable power law is found, whatever the text, $r = n^\lambda$, with $\lambda = 0.79$, which does not indicate any saturation. It seems of great interest to examine other authors and to find whether λ characterizes some style or author or

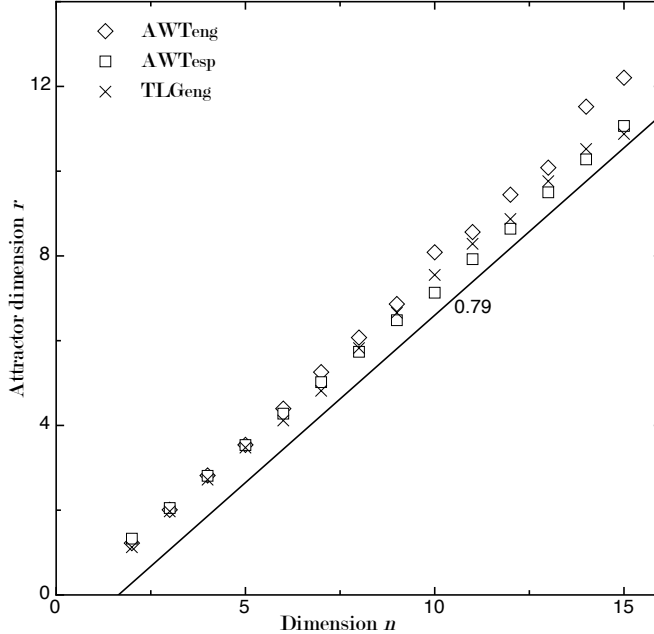


Fig. 8. Attractor dimension n as a function of the so called phase space dimension r for the three texts of interest. Notice that a linear relationship is found with a proportionality coefficient $\lambda = 0.79$ on a log-log plot, as for $r = n^\lambda$

4 Conclusion

At first sight, a time series of a single variable appears to provide a limited amount of information. We usually think that such a series is restricted to a one-dimensional view of a system, which, in reality, contains a large number of independent variables. On one hand FTS and LTS result from a dynamical process, which is usually first characterized by its fractal dimension. The first approach should contain a mere statistical analysis of the output, as done through a Zipf like analysis. It can be found that analytical forms, like power laws with different characteristic exponents for the ranking properties exist. The Zipf exponent can take values *ca.* 1.0, 0.50 or 0.30, depending on how a sentence is defined. This non-universality is conjectured to be a measure of the author *style*. Another approach through a Zipf-Mandelbrot law seems unreliable due to the (present lack) of distinction most likely between function and determining words, and breaks occurring in the $f(R)$ plots. Something which has not been examined and is left for further studies is the distinction between oral-like and descriptive parts of a ttext and its translation.

Moreover a time series is known [48,49,75] to bear the marks of all other variables participating in the dynamics of the system. Thus one is able to reconstruct the systems phase space from such a series of one-dimensional observations. When applying the Grassberger-Proccacia (GP) method to a physics time series one wants to know whether the attractor is based on a finite

set of variables. The lack of saturation found here through the law $r = n^\lambda$ for the size of the attractor indicates that the writing of a text by some creative author can be hardly reduced to a finite set of differential equations ! Yet the analytical form suggests to examine whether λ characterizes an author style or creativity, and how robust its value can be.

Finally, as in [20] we concur that the application of GP analysis indicates that linguistic signals may be considered as the manifestation of a complex system of high dimensionality, different from random signals or systems of low dimensionality such as the Earth climate or financial signals.

Last but not least as on comparing AWLeng, AWL_{esp} , and TLGeng, with both the "static" and "dynamic" methods, it seems that the texts are qualitatively similar, which indicates ... the quality of the translator. In this spirit, it would be interesting to compare with results originating from text obtained through a machine translation, as recently studied in [84]. It is of huge interest to see whether a machine is *more flexible* with vocabulary and grammar than a human translator, - see also [43]!

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5 Appendix

The Zipf-Mandebrot, Eq.(2), law is thought to be useful for better describing the ranking function $f(R)$, in particular in order to take into account the finite value of f at $R \simeq 1$. Yet from data presented in Table 3, it can be observed that the parameters, in particular ζ^* is far from robust when the range of R slightly varies. For example ζ^* can vary from 0.84 to 3.61 when only the fit range is slightly changed, like in the case of Fig. 5b, for sentences limited by question marks in the three original texts where one expects an exponent near 0.5. It appears that if one fits from $R=1$ one finds $\zeta^*=0.65$,

AWLeng	parameter	value	absolute error
Range : from 2 to 200	A	2104.5665	102.1277
	C	1.2151	0.2201
	ζ^*	0.3924	6.1668e-3
Range : from 2 to 200	A	1239.7700	18.5571
	C	0.1553	1.1255e-2
	ζ^*	0.4874	7.7509e-3
Range : from 3 to 200	A	1105.3531	10.7540
	C	9.4509e-2	4.7342e-3
	ζ^*	0.5334	6.9828e-3
Range : from 4 to 200	A	1061.8008	9.7680
	C	7.9410e-2	3.7663e-3
	ζ^*	0.5526	7.1248e-3

Table 5

Effect of low ranking points on Z-M fit; parameter values and their corresponding error bar for AWLeng sentences limited by "dots"

but from $R=2$, $\zeta^*=1.68$, from $R=3$, $\zeta^*=2.68$, and from $R=4$ $\zeta^*=3.61$, as shown in Table 3. This is "obviously" due to the curvature of the data at low R . Some other example pointing to the probable origin of the fit parameter value instability. in AWLeng defined through dots in Fig.1 is given in Table 4, where a few results of small changes in ranges, removing one, two, three or four first points, and the corresponding parameter fits are given with the (absolute) error bars.

I have not found much discussion of the matter in the literature, maybe because either the case is not frequent, or not examined. See nevertheless [85] where it is suggested that ζ^* be interval dependent and increasing logarithmically with R . In the present case, it appears that one can consider the origin of the instability to reside in the "large" variations of $f(R)$ at small R . In fact the curvature of $f(R)$ changes from convex to concave at small R . This leads to an instability in the set of least mean square fits. This, in other words, is due to the number of regimes, changes in curvature, in the data. Powers [15] (and later others like [59]) had already noticed that one should distinguish between small (function) words and large (determining) words, and pointed to the break, or change in slope at finite R (~ 100). A recommendation is in order : a visual scan of the data should be made before attempting a fit with Eq.(2), in order to observe the number of regimes, or the number of crossover points, which might appear in the data. It is also of course useless to attempt a fit with many more parameters, - one would need at least three per regime! Yet the understanding of the position of the crossover points might be of interest. Recall the remarkable papers on the position of the cross over points in detrended fluctuation analysis studies [86,87], related to a periodic background or trend in time series. Such considerations would illuminate in the present context, the language quality level or an author style and creativity through a text "background" content..

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